MA 35: Caloric effects in ferromagnetic materials

Time: Wednesday 15:00–17:00 Location: H52

MA 35.1 Wed 15:00 H52

A multicaloric cooling cycle that exploits hysteresis — •Tino Gottschall[1,2], Adrià Gràcia-Condal[3], Maximilian Fries[2], Andreas Taubel[2], Lukas Pfeuffer[2], Lluís Mañosa[3], Antoni Planes[3], Konstantin P. Skokov[2], and Oliver Gutfleisch[2] — [1]Dresden High Magnetic Field Laboratory, HZDR, Germany — [2]Faculty of Materials Science, TU Darmstadt, Germany — [3]Facultat de Física, Universitat de Barcelona, Barcelona, Spain

The giant magnetocaloric effect, in which large thermal changes are induced in a material on the application of a magnetic field, can be used for refrigeration applications, such as the cooling of systems from a small to a relatively large scale. However, commercial uptake is limited. We propose an approach to magnetic cooling that rejects the conventional idea that the hysteresis inherent in magnetostructural phase-change materials must be minimized to maximize the reversible magnetocaloric effect. Instead, we introduce a second stimulus, uniaxial stress, so that we can exploit the hysteresis [1]. This allows us to lock-in the ferromagnetic phase as the magnetizing field is removed, which drastically reduces the volume of the magnetic field source and so reduces the amount of expensive Nd-Fe-B permanent magnets needed for a magnetic refrigerator. The technical feasibility of this hysteresis-positive approach is demonstrated using Ni-Mn-In Heusler alloys. Our study could lead to an enhanced usage of the giant magnetocaloric effect in commercial applications.

[1] T. Gottschall et al., Nat. Mater. **17**, 929 (2018).

MA 35.2 Wed 15:15 H52

Unraveling the role of hydrogen on the vibrational and magnetic properties of $LaFe_{13-x}Si_xH_y$ — •Markus E. Gruner[1], Alexandra Terwey[1], Joachim Landers[1], Soma Salamon[1], Werner Keune[1], Katharina Ollefs[1], Valentin Brabänder[2], Iliya Radulov[2], Konstantin Skokov[2], Jiyong Zhao[3], Michael Y. Hu[3], Thomas S. Toellner[3], Ercan E. Alp[3], Oliver Gutfleisch[2], and Heiko Wende[1] — [1]Universität Duisburg-Essen — [2]TU Darmstadt — [3]Argonne National Laboratory

$LaFe_{13-x}Si_x$ is one of the most promising candidates for magnetic refrigeration applications. Its favorable first-order magnetic transition is connected to the itinerant electron metamagnetism of Fe, while loading with hydrogen allows to shift T_C to ambient conditions. To avoid decomposition into low- and high-T_C regions, full loading is mandatory, which occupies only a part of the (24d) interstitial sites. Our density functional theory (DFT) calculations reveal that hydrogen strongly disfavors the presence of Si close to the interstitial sites. By combining DFT and nuclear resonant inelastic X-ray scattering (NRIXS), we identify adiabatic electron-phonon coupling as the microscopic mechanism causing the beneficial cooperative interplay between electronic, magnetic and vibrational degrees of freedom in $LaFe_{13-x}Si_xH_y$. In addition, we discuss the impact of interstitial hydrogen on the magnetic interactions between the different Fe sites and give an oulook on the impact of a partial substitution of Fe with other transition metals on the vibrational properties.
Funding by the DFG within SPP 1599 is gratefully acknowledged.

MA 35.3 Wed 15:30 H52

Local structural analysis of $La(Fe,Si)_{13}$-compounds — •Cynthia Pillich[1], Alexandra Terwey[1], Katharina Ollefs[1], Benedikt Eggert[1], Daniela Trienes[1], Markus E. Gruner[1], Werner Keune[1], Valentin Brabänder[2], Iliya Radulov[2], Konstantin Skokov[2], Oliver Gutfleisch[2], Mauro Rovezzi[3,4], and Heiko Wende[1] — [1]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany — [2]Materials Science, Technical University Darmstadt, 64287 Darmstadt, Germany — [3]Observatoire des Sciences de l'Univers de Grenoble (OSUG), UMS 832 CNRS, Univ. Grenoble Alpes, F-38041 Grenoble, France — [4]3BM30B/CRG-FAME, ESRF, Polygone Scientifique Louis Nèel, 71 avenue des Martyrs, 38000 Grenoble, France

$La(Fe,Si)_{13}$-compounds show excellent magnetocaloric properties due to an isostructural volume decrease upon increasing temperature, accompanying a first-order magnetostructural transition, and therefore is used in solid state refrigeration. By analyzing the Extended X-Ray Absorption Fine Structure (EXAFS) at the Fe K- and La L_3-edge we can observe the influence of Mn-doping on the local surrounding of the atoms in $La(Fe,Si)_{13}$. The measurements were performed for different Mn-concentrations in the 1:13 system as well as varying temperatures. A lattice contraction at the phase transition from the FM to the PM state was observed. Comparing the experimental data with a theoretically modeled EXAFS signal gives insight into the local lattice configuration. Funding by the DFG (SPP1599) is acknowledged.

MA 35.4 Wed 15:45 H52

Element-specific view on $La(FeSi)_{13}$ — •Katharina Ollefs[1], Markus E. Gruner[1], Alexandra Terwey[1], Benedikt Eggert[1], Iliya Radulov[2], Konstantin Skokov[2], Werner Keune[1], Fabrice Wilhelm[3], Andrei Rogalev[3], Oliver Gutfleisch[2], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg- Essen, Germany — [2]Functional Materials, Technical University Darmstadt, Darmstadt, Germany — [3]Synchrotron Radiation Facility, Grenoble, France

Due to its large magneto-caloric effect, the itinerant electron metamagnet $La(FeSi)_{13}$ is of great interest for its potential use in solid state refrigeration. In order to better understand the magnetic interactions in this material and how they change at the transition, we have performed x-ray absorption measurements. X-ray magnetic circular dichroism measurements in the low temperature phase at the Fe K-edge and La $L_{2,3}$-edges reveal not only a magnetic moment on Fe but also a sizable magnetic moment in the 5d states of La. Magneto-optical sum-rule analysis and DFT calculations indicate an anti-parallel alignement of the Fe and La spin moment and a small orbital moment on La also anti-parallel to spin moment. Disentangling the different magnetic moment contributions in $La(FeSi)_{13}$ may reveal additional sources for hysteresis and might shed light on the thermodynamic role of the particular magnetic degrees of freedom. Funding by the DFG (SPP1599) is acknowledged.

MA 35.5 Wed 16:00 H52

Spin Seebeck effect and ballistic transport of quasi-acoustic magnons in room-temperature yttrium iron garnet films — •Timo B. Noack[1], Halyna Yu. Musiienko-Shmarova[1], Thomas Langner[1], Frank Heussner[1], Viktor Lauer[1], Björn Heinz[1], Dmytro A. Bozhko[1], Vitaliy I. Vasyuchka[1], Anna Pomyalov[2], Victor L'vov[2], Burkard Hillebrands[1], and Alexander A. Serga[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Kaiserslautern, Germany — [2]Department of Chemical and Biological Physics, Weizmann Institute of Science, Rehovot, Israel

We study the transient behavior of the spin current generated by the Longitudinal Spin Seebeck Effect (LSSE) in a set of platinum-coated Yttrium Iron Garnet (YIG) films of different thicknesses. The LSSE is induced by means of pulsed microwave heating of the Pt layer and the spin currents are measured electrically using the inverse spin Hall effect. We demonstrate that the time evolution of the LSSE is determined by the evolution of the thermal gradient triggering the flux of thermal magnons in the vicinity of the YIG/Pt interface. These magnons move ballistically within the YIG film with constant group velocity. The ballistic flight of the magnons with energies above 20 K is a result of their almost linear dispersion law, similar to that of acoustic phonons. By fitting the time-dependent LSSE signal for different film thicknesses varying by almost an order of magnitude, we found that the effective propagation length is practically independent of the YIG film thickness.

MA 35.6 Wed 16:15 H52

Millisecond Dynamics of the Magnetocaloric Effect in a First- and Second-Order Phase Transition Material — •Jago Döntgen, Jörg Rudolph, and Daniel Hägele — AG Spektroskopie d. kond. Materie, Ruhr-Universität Bochum

One of the key challenges of the research in magnetocaloric materials is a reliable determination of the adiabatic temperature change ΔT. We have developed a novel method for direct measurements of ΔT that allows for the investigation of the magnetocaloric effect on length- and time-scales inaccessibly by traditional calorimetry. Our technique is based on the application of temporally oscillating magnetic fields and detection of the resulting change of the thermal radiation emitted by

the sample. We achieve a unique combination of a sensitivity of better than 1 mK, a time-resolution of 10 μs, and magnetic field modulation frequencies exceeding 1 kHz [1]. We present dynamic measurements of the magnetocaloric effect, that allow for a direct distinction between reversible and irreversible sample behavior. The ΔT dynamics of the first-order phase transition material $La_{1.2}Fe_{11.4}Si_{1.4}Mn_{0.2}H_y$ show a peculiar self-quenching at temperatures slightly below the peak maximum.[2] This behavior can be attributed to the first-order nature of the phase transition, which takes place at the phase boundary between the paramagnetic and ferromagnetic sample regions.

[1] Döntgen et al., Rev. Sci. Instrum. **89**, 033909 (2018)
[2] Döntgen et al., Energy Technol. **6**, 1470-1477 (2018)

MA 35.7 Wed 16:30 H52

Magnetocaloric potential of Ni-Mn-(In,Sn,Al) Heusler alloys in case of complete martensite-to-austenite transformation in high magnetic fields — •Franziska Scheibel[1], Andreas Taubel[1], Lukas Pfeuffer[1], Tino Gottschall[2], and Oliver Gutfleisch[1] — [1]Funktionale Materialien, Technische Universität Darmstadt, Germany — [2]Hochfeld- Magnetlabor Dresden, Helmholtz-Zentrum Dresden-Rossendorf, Germany

Ni-Mn-based Heusler are known as potential materials for magnetic refrigeration, due to their large magnetocaloric effect during first-order magnetostructural transformation (FOMST). The challenge of the thermal hysteresis of the FOMST becomes an advantage by using a new cooling cycle concept, which introduces a second stimulus (uniaxial stress) besides the magnetic field[1]. The new concept enables the reduction of the permanent magnet volume and the duration of the magnetic field application which allows an increase in the field.
We show the magnetocaloric potential of Ni-Mn-(In, Sn, Al) Heusler alloys by direct adiabatic temperature change ΔT_{ad} measurements in pulsed magnetic fields up to 30 T inducing a complete martensite-to-austenite transformation. Thereby, the MCE of different Heusler alloys can be compared by considering the max. ΔT_{ad} for a complete transformation rather than comparing minor-loop transformation in 1 or 2 T. As an example, a ΔT_{ad} of -17 K is measured in $Ni_{46}Mn_{38}Sn_{11}Co_5$ for a 20 T field pulse.
The work is supported by the ERC advanced grand *Cool Innov*.
[1] T. Gottschall et al., Nature Materials 17, 929-934 (2018)

MA 35.8 Wed 16:45 H52

Investigation of microstructure and magnetocaloric properties of Ni-Co-Mn-Ti Heusler alloys — •Andreas Taubel, Benedikt Beckmann, Lukas Pfeuffer, Franziska Scheibel, Maximilian Fries, Tino Gottschall, Konstantin P. Skokov, and Oliver Gutfleisch — TU Darmstadt, Alarich-Weiss-Straße 16, 64287 Darmstadt

Ni-Mn-X(-Co) Heusler alloys show a martensitic transformation that can be coupled to a magnetic phase change resulting in promising properties for magnetocaloric applications [1,2]. Recently, the principle of all-d metal Heusler alloys has been introduced by placing d-metal elements on the X site for those alloys. Especially the systems with X=Ti have been studied as promising materials due to a large magnetization change, good tunability of the phase transition and enhanced mechanical properties.

In this work, we report on the microstructural properties of Ni-rich $Ni_{50-x}Co_xMn_{50-y}Ti_y$ and Mn-rich $Mn_{50}Ni_{50-x-y}Co_xTi_y$ alloys. By optimizing the processing route of the novel Ni-Mn-Ti system, we could improve the inverse magnetostructural phase transition in terms of sharpness and magnetization change. A large isothermal entropy change of up to 38 $Jkg^{-1}K^{-1}$ has been measured for a magnetic field change of 2T by isofield protocol.

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[1] A. Taubel et al., physica status solidi (b) 255 (2), 1700331 (2018)
[2] T Gottschall et al., Nature materials 17 (10), 929 (2018)